DOCUMENT RESUME

ED 046 683 SE 008 163

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TITLE Pupils' Reactions to Trial Editions of Nuffield 'O'-Level Science Materials in 1966.
INSTITUTION Macquarie Univ., North Ryde (Australia).
SPONS AGENCY Nuffield Foundation, London (England).
PUB DATE Jan 69
NOTE 39p.

EDRS PRICE EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS *Attitudes, Biology, Chemistry, *Curriculum, *Evaluation, *Interests, Physics, *Secondary School Science, Student Science Interests
IDENTIFIERS England

ABSTRACT

Scientific attitudes and interests of fifth form students who had had at least two years of experimental Nuffield O-Level courses in biology, physics, and chemistry were compared with those of equivalent students studying traditional courses. The author-developed tests contained Likert-type items measuring interests in science, attitudes to the teaching of science in particular schools, scientific thinking and attitudes, interests in scientific hobby or leisure activities, interest in solving problems by practical activity rather than appeal to authority, and interest in science as a body of facts. The major statistically significant results were as follows. The Nuffield Programs: (1) improved scientific interests and attitudes of girls, but not boys; (2) increased interest in empiricism and science as a leisure activity, but not in scientific facts; (3) did not transfer interest in facts to other disciplines; (4) caused a decline in interest in fine-arts and literature; (5) caused a loss of scientific interest by male physics students; (6) over-emphasized inquiry; and (7) caused an overall improvement in scientific thinking. Hypotheses to explain the findings were made. (AL)

# PUPILS' REACTIONS TO TRIAL EDITIONS OF NUFFIELD 'O'-LEVEL SCIENCE MATERIALS IN 1966

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A Report to the Nuffield Foundation of an Investigation Completed with the Aid of a Nuffield Foundation Special Study Grant, March to August, 1966.



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NOTE: As the results of this study have not yet been published, this report should not be copied or referred to in other publications without permission from both the Nuffield Foundation and the author. Enquiries to the author.

Macquarie University, Centre for Advancement of Teaching

January 1969

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# REACTIONS OF PUPILS TO 'O' LEVEL G.C.E. NUFFIELD TRIAL MATERIALS IN ENGLAND

## RESULTS OF A PRELIMINARY RESEARCH STUDY

G.R.Meyer(+)

An investigation was made of scientific attitudes and interests amongst fifth form secondary school pupils in England who had had at least two years experience of a Nuffield 'O'-level G.C.E. Science course since the third form (1).

Comparisons were made with equivalent pupils taking conventional science courses for the G.C.E. (2). Interviews, tests and questionnaires were administered during the period March to August 1966.

This study was supported by a Special Study Grant from the Nuffield Foundation (3).

### Selection of Schools and Pupils

1226 fifth form pupils were included in the study, of these 546 pupils were in the Non-Nuffield "control" or "traditional" group and 680 in the Nuffield "experimental" group. All pupils in the experimental group had studied two other science subjects, following conventional syllabuses. All those pupils in the control traditional group were studying all three sciences, Biology, Chemistry and Physics for the 'O'-level General Certificate of Education (G.C.E.).

The two groups were matched as closely as possible. Ages and abilities were made closely equivalent by restricting each group to fifth form students enrolled in two or three science subjects for 'O'-level G.C.E. The types and locations of schools were matched quite closely. For instance there were equivalent numbers of grammar, comprehensive, maintained and public schools and both urban and rural districts were included in each group. The proportions of sexes in the two groups, however, were not exactly equivalent. There were rather more boys than girls in the experimental group and the sexes were about equally divided in the control group - see Table 1.

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Table 1. The numbers and percentages of boys and girls in the Control and Experimental Groups.

| | CONTROL (Non-Nuffield) i.e. Traditional | | EXPERIMENTAL (Nuffield) | |
|---|---|---|---|---|
| | No. | % | No. | % |
| Boys | 285 | 52.2 | 470 | 69.1 |
| Girls | 261 | 47.8 | 210 | 30.9 |
| | 546 | 100.0 | 680 | 100.0 |

The experimental group came from all those schools able to co-operate from a list provided by the Nuffield Science Teaching Project. This list included all the schools with candidates enrolled for Nuffield 'O'-level G.C.E. science papers for the examinations of June 1966. The total numbers of schools and pupils in this group and the numbers who co-operated in the final experimental study are shown in Table 2.

Table 2. The numbers of schools and pupils taking Nuffield Science Papers at the 'O'-level G.C.E. Examinations in 1966 compared with the numbers in the experimental group.

| Course | Numbers taking Nuffield Courses 1966 | | Numbers in Experimental Group | |
|---|---|---|---|---|
| | Schools * | Pupils + | Schools | Pupils |
| Nuffield Chemistry | 17 | 677 | 5 | 221 |
| Nuffield Physics | 8 | 257 | 6 | 209 |
| Nuffield Biology | 18 | 615 | 10 | 250 |
| Totals | 43 | 1549 | 21 | 680 |

* Omitting Schools with less than ten candidates.

\+ All pupils entered for a Nuffield O-level Science examination in June 1966.

Table 2 shows that of the total available experimental population about half was included in the study. The Nuffield Chemistry group was sampled from only 5 schools (*) and as this is not as representative as for the physics and biology, the chemistry results should be interpreted with relative caution. In addition the number of girls taking Nuffield Physics & Nuffield Chemistry were relatively small and so results involving these sub-groups should be interpreted with this in mind.

The selection of a control group (546 pupils from eight schools) was largely pre-determined. In an attempt to reduce the "Hawthorn" effect (i.e. the professional bias and natural enthusiasms of a teacher who had chosen to introduce a Nuffield Science programme), the "Control" Schools were, with one exception, selected from those which had not yet introduced Nuffield science, but which had volunteered to act as trial schools for new 'A' -level Nuffield courses. The exceptional school was, for administrative reasons, unable to act as a trial school for A-level but was very sympathetic to the ideals of the Nuffield programmes. As far as possible, therefore, the control and experimental schools, were equally matched from the point of view of the attitude of staff to the Nuffield ideal. After other factors had been matched the list of possible control schools reduced to the final eight.

It was felt that after this careful sampling and selection, any significant differences detected between the scientific attitudes and interests of pupils in the control and experimental groups could be fairly attributed to whether or not the pupils had taken science courses designed by the Nuffield Science Teaching Project.

Variables Measured

Pupils completed tests designed to assess levels of interest in and attitudes towards various aspects of science in their schools. In addition, for purposes of contrast, some assessments were made of interest in non-scientific subjects. All the tests involved the subjective rating of Likert-type items using the method of absolute summation. All but one of these tests are described in some detail elsewhere[4]. The remaining test, an assessment of

(*) Because of administrative difficulties at the close of term, the remaining 12 possible schools asked to be omitted from the survey.

sophistication in scientific attitude, was developed especially for this survey. The tests have since been printed as a booklet(5), but are as yet unpublished.

A main score called "Scientific Orientation" or "S.O." was derived from the tests. The S.O. score consisted of the following components.

S.O. = Interest in Science (Affective) + Attitude to the Teaching of Science in the particular School (Affective) + Scientific Thinking or Attitude (Cognitive and Affective). The scores were on a scale from -80 to +200.

Weightings within the S.O. Score were -

| | |
|---|---|
| Interest | 44% |
| Attitude | 28% |
| Thinking | 28% |

The interest component carried most weight because it was derived from a number of sub-scores, giving greatest reliability and validity to measures of interest.

The sub-scores 'Attitude to the Teaching of Science in the School', and 'The Scientific Thinking (Attitude)' scores were not subdivided further; but the sub-score "Interest in Science" was derived from the addition of three internal scores as follows.

1. Interest in a scientific hobby or leisure activity.
2. Interest in solving problems in science by practical activity in contrast to appeal to authority; that is, interest in science as a method of solving problems.
3. Interest in science as a body of facts.

The test also enabled further scores to be taken out for interest in various areas of scientific content - Physics, Biology, Chemistry, Astronomy, Geology and History of Science. Assessment of overall interest in scientific facts was expressed as the mean of scores from these six areas.

Apart from the S.O. score and its various sub-divisions five scores were made of interest in areas science experts considered to be "non-scientific". These areas were interests in Fine Art and Literature as leisure-time activities and interest in solving problems in science by appeal to authority rather than by personal experiment. Three types of authority were

selected as possible sources of answers to problems in science - experts, books and teachers.

The sex of the student and his ambition were noted. By ambition was meant whether or not the student wanted to be a science major or non-science major in his sixth form.

Table 3 lists the variables measured, gives the theoretical ranges of scaled scores obtainable from each test, and lists the name or symbol of the relevant sub-tests in the test booklet (6) from which the scores were derived.

Table 3. Variables Measured

| Variable | | Scale | Name and/or symbol of sub-test in Test Booklet |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 | Interest in Science | 0 - 120 | Total Interest $T_1$ |
| 1.1 | As a leisure interest | 0 - 40 | School Holidays - $S_1$ |
| 1.2 | As a method of solving scientific problems | 0 - 40 | Finding Out About Things - $S_2$ |
| 1.3 | As a set of facts | 0 - 40 | Learning Things - Mean $S_3$ |
| | 1.31 Physics facts | 0 - 40 | Learning Things - P |
| | 1.32 Biology facts | 0 - 40 | Learning Things - B |
| | 1.33 Chemistry facts | 0 - 40 | Learning Things - C |
| | 1.34 Astronomy facts | 0 - 40 | Learning Things - A |
| | 1.35 Geology facts | 0 - 40 | Learning Things - G |
| | 1.36 Science History facts | 0 - 40 | Learning Things - H |
| 2.0 | Scientific Thinking | - 40 - +40 | Talking Together $T_2$ |
| 3.0 | Attitude to Science Teaching in the School | - 40 - +40 | Science in Your School $T_3$ |
| 4.0 | Ambition (1= non Science 6th 2= Science 6th ) | 1 - 2 | - |
| 5.0 | Science Orientation (S.O.) 1.0 (44%) + 2.0 (28%) + 3.0 (28%) | - 80 -+200 | $T_1 + T_2 + T_3$ |
| NON-SCIENTIFIC | | | |
| 6.0 | Non-Science Interests | | |
| | 6.1 Fine Art | 0 - 40 | School Holidays - A |
| | 6.2 Literature | 0 - 40 | School Holidays - L |
| 7.0 | Interest in Solving Problems by appeal to authority | | |
| | 7.1 Asking an Expert | 0 - 40 | Finding Out About Things - E |
| | 7.2 Reading a Book | 0 - 40 | Finding Out About Things - B |
| | 7.3 Asking a Teacher | 0 - 40 | Finding Out About Things - T |

Administration of Tests

The pupils in both experimental and control schools were all tested personally by the author or his representative after taking considerable care to establish suitable rapport between test administrator and subject. The pupils were assured of anonymity and given a guarantee that no-one in their school would see the results from that school. All pupils responded with interest and enthusiasm and appeared willing and anxious to express their opinions.

On-spot checks of validity were made by asking all pupils to write essays on their attitudes and interests and by interviewing selected pupils. All teachers involved were interviewed in depth. This qualitative data gave assurance that the test results were highly valid.

## Results

Various sub-groups were identified and the following sub-groups were compared.

1. Total Boys and Total Girls.
2. Total Nuffield and Total Traditional.
3. Nuffield Biology and Total Traditional.
4. Nuffield Chemistry and Total Traditional.
5. Nuffield Physics and Total Traditional.
6. Nuffield Boys and Traditional Boys.
7. Nuffield Biology Boys and Traditional Boys.
8. Nuffield Chemistry Boys and Traditional Boys.
9. Nuffield Physics Boys and Traditional Boys.
10. Nuffield Girls and Traditional Girls.
11. Nuffield Biology Girls and Traditional Girls.
12. Nuffield Chemistry Girls and Traditional Girls.
13. Nuffield Physics Girls and Traditional Girls.

The means and standard deviations of the scores on each of the variables listed in Table 3 are set out in statistical tables in the Appendix. Inter-correlations of scores of the twenty variables are also shown in the Appendix, separately for Nuffield and Traditional pupils.

The results of comparisons between the various sub-groups are presented in Tables 4 to 16.

table 4. Comparisons between boys and girls

Boys $N_1 = 755$ Girls $N_2 = 471$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 4.748 | 0.001 | Boys |
| 1.1 Leisure interest | 11.087 | 0.001 | Boys |
| 1.2 As a method | 0.408 | N.S. | |
| 1.3 As facts | 0.133 | N.S. | |
| 1.31 Physics facts | 11.767 | 0.001 | Boys |
| 1.32 Biology facts | 9.673 | 0.001 | Girls |
| 1.33 Chemistry facts | 7.273 | 0.001 | Boys |
| 1.34 Astronomy facts | 0.188 | N.S. | |
| 1.35 Geology facts | 2.523 | 0.02 | Girls |
| 1.36 Science history facts | 5.655 | 0.001 | Girls |
| 2.0 Scientific thinking | 0.131 | N.S. | |
| 3.0 Attitude to school science | 4.396 | 0.001 | Boys |
| 4.0 Scientific ambition | 4.250 | 0.001 | Boys |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 4.438 | 0.001 | Boys |
| NON-SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 13.510 | 0.001 | Girls |
| 6.2 Literature | 15.631 | 0.001 | Girls |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.475 | N.S. | |
| 7.2 Reading a book | 1.748 | N.S. | |
| 7.3 Asking a teacher | 4.404 | 0.001 | Girls |

table 5. Comparisons between Nuffield (Experimental) pupils and Traditional (Control) pupils.

Nuffield $N_1$ = 680 Traditional $N_2$ = 546

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 3.114 | 0.01 | Nuffield |
| 1.1 Leisure interest | 3.063 | 0.01 | Nuffield |
| 1.2 As a method | 3.689 | 0.001 | Nuffield |
| 1.3 As facts | 0.100 | N.S. | |
| 1.31 Physics facts | 1.684 | N.S. | |
| 1.32 Biology facts | 0.078 | N.S. | |
| 1.33 Chemistry facts | 1.855 | N.S. | |
| 1.34 Astronomy facts | 0.021 | N.S. | |
| 1.35 Geology facts | 1.399 | N.S. | |
| 1.36 Science history facts | 1.688 | N.S. | |
| 2.0 Scientific thinking | 3.579 | 0.001 | Nuffield |
| 3.0 Attitude to school science | 2.477 | 0.02 | Nuffield |
| 4.0 Scientific ambition | 4.308 | 0.001 | Nuffield |
| 5.0 Science orientation (S.O) (1.0 + 2.0 + 3.0) | 3.388 | 0.001 | Nuffield |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.900 | 0.01 | Traditional |
| 6.2 Literature | 1.572 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.025 | N.S. | |
| 7.2 Reading a book | 3.175 | 0.01 | Traditional |
| 7.3 Asking a teacher | 4.417 | 0.001 | Traditional |

table 6. Comparisons between pupils taking Nuffield Biology and Traditional Science.

Nuffield Biology $N_1 = 250$ Traditional $N_2 = 546$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 0.473 | N.S. | |
| 1.1 Leisure interest | 1.109 | N.S. | |
| 1.2 As a method | 2.832 | 0.01 | Nuffield Biology |
| 1.3 As facts | 1.075 | N.S. | |
| 1.31 Physics facts | 1.501 | N.S. | |
| 1.32 Biology facts | 3.136 | 0.01 | Nuffield Biology |
| 1.33 Chemistry facts | 0.357 | N.S. | |
| 1.34 Astronomy facts | 2.697 | 0.01 | Traditional |
| 1.35 Geology facts | 1.407 | N.S. | |
| 1.36 Science history facts | 0.893 | N.S. | |
| 2.0 Scientific thinking | 3.117 | 0.01 | Nuffield Biology |
| 3.0 Attitude to school science | 0.936 | N.S. | |
| 4.0 Scientific ambition | 3.048 | 0.01 | Nuffield Biology |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 1.330 | N.S. | |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 1.616 | N.S. | |
| 6.2 Literature | 0.500 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 1.059 | N.S. | |
| 7.2 Reading a book | 2.627 | 0.01 | Traditional |
| 7.3 Asking a teacher | 2.988 | 0.01 | Traditional |

table 7. Comparisons between pupils taking Nuffield Chemistry and Traditional Science.

Nuffield Chemistry $N_1 = 221$ Traditional Science $N_2 = 546$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 6.151 | 0.001 | Nuffield Chemistry |
| 1.1 Leisure interest | 7.303 | 0.001 | Nuffield Chemistry |
| 1.2 As a method | 3.463 | 0.001 | Nuffield Chemistry |
| 1.3 As facts | 2.150 | 0.05 | Nuffield Chemistry |
| 1.31 Physics facts | 3.936 | 0.001 | Nuffield Chemistry |
| 1.32 Biology facts | 1.186 | N.S. | |
| 1.33 Chemistry facts | 4.514 | 0.001 | Nuffield Chemistry |
| 1.34 Astronomy facts | 1.501 | N.S. | |
| 1.35 Geology facts | 1.067 | N.S. | |
| 1.36 Science history facts | 1.342 | N.S. | |
| 2.0 Scientific thinking | 3.333 | 0.001 | Nuffield Chemistry |
| 3.0 Attitude to school science | 4.493 | 0.001 | Nuffield Chemistry |
| 4.0 Scientific ambition | 2.997 | 0.01 | Nuffield Chemistry |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 5.858 | 0.001 | Nuffield Chemistry |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.497 | 0.02 | Traditional |
| 6.2 Literature | 3.440 | 0.001 | Traditional |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 1.521 | N.S. | |
| 7.2 Reading a book | 0.154 | N.S. | |
| 7.3 Asking a teacher | 2.334 | 0.02 | Traditional |

table 8. Comparisons between pupils taking Nuffield Physics and Traditional Science.

Nuffield Physics $N_1 = 209$ Traditional $N_2 = 546$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 0.774 | N.S. | |
| 1.1 Leisure interest | 1.277 | N.S. | |
| 1.2 As a method | 1.078 | N.S. | |
| 1.3 As facts | 0.604 | N.S. | |
| 1.31 Physics facts | 1.616 | N.S. | |
| 1.32 Biology facts | 2.083 | 0.05 | Traditional |
| 1.33 Chemistry facts | 0.289 | N.S. | |
| 1.34 Astronomy facts | 1.443 | N.S. | |
| 1.35 Geology facts | 2.727 | 0.01 | Traditional |
| 1.36 Science history facts | 1.522 | N.S. | |
| 2.0 Scientific thinking | 1.267 | N.S. | |
| 3.0 Attitude to school science | 0.358 | N.S. | |
| 4.0 Scientific ambition | 3.475 | 0.001 | Nuffield Physics |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 0.691 | N.S. | |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.229 | 0.05 | Traditional |
| 6.2 Literature | 0.648 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.341 | N.S. | |
| 7.2 Reading a book | 4.383 | 0.001 | Traditional |
| 7.3 Asking a teacher | 3.969 | 0.001 | Traditional |

table 9. Comparisons between boys taking Nuffield Science and boys taking Traditional Science.

Nuffield Boys $N_1$ = 470 Traditional Boys $N_2$ = 285

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 0.023 | N.S. | |
| 1.1 Leisure interest | 0.724 | N.S. | |
| 1.2 As a method | 1.933 | N.S. | |
| 1.3 As facts | 1.553 | N.S. | |
| 1.31 Physics facts | 1.976 | 0.05 | Traditional Boys |
| 1.32 Biology facts | 0.775 | N.S. | |
| 1.33 Chemistry facts | 1.079 | N.S. | |
| 1.34 Astronomy facts | 1.727 | N.S. | |
| 1.35 Geology facts | 1.727 | N.S. | |
| 1.36 Science history facts | 2.399 | 0.02 | Traditional Boys |
| 2.0 Scientific thinking | 1.491 | N.S. | |
| 3.0 Attitude to school science | 0.408 | N.S. | |
| 4.0 Scientific ambition | 0.535 | N.S. | |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 0.050 | N.S. | |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 0.995 | N.S. | |
| 6.2 Literature | 0.931 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.511 | N.S. | |
| 7.2 Reading a book | 2.212 | 0.05 | Traditional Boys |
| 7.3 Asking a teacher | 2.208 | 0.05 | Traditional Boys |

table 10. Comparisons between boys taking Nuffield Biology and boys taking Traditional Science.

Nuffield Biology Boys $N_1$ = 131 Traditional Boys $N_2$ = 285

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 0.427 | N.S. | |
| 1.1 Leisure interest | 0.930 | N.S. | |
| 1.2 As a method | 2.371 | 0.02 | Nuffield Biology Boys |
| 1.3 As facts | 0.946 | N.S. | |
| 1.31 Physics facts | 1.720 | N.S. | |
| 1.32 Biology facts | 3.969 | 0.001 | Nuffield Biology Boys |
| 1.33 Chemistry facts | 0.251 | N.S. | |
| 1.34 Astronomy facts | 3.115 | 0.01 | Traditional Boys |
| 1.35 Geology facts | 2.194 | 0.05 | Traditional Boys |
| 1.36 Science history facts | 0.029 | N.S. | |
| 2.0 Scientific thinking | 2.145 | 0.05 | Nuffield Biology Boys |
| 3.0 Attitude to school science | 0.079 | N.S. | |
| 4.0 Scientific ambition | 2.741 | 0.01 | Nuffield Biology Boys |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 0.646 | N.S. | |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 0.742 | N.S. | |
| 6.2 Literature | 0.248 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.625 | N.S. | |
| 7.2 Reading a book | 1.179 | N.S. | |
| 7.3 Asking a teacher | 1.700 | N.S. | |

table 11. Comparisons between boys taking Nuffield Chemistry and boys taking Traditional Science.

Nuffield Chemistry Boys $N_1 = 169$ Traditional Boys $N_2 = 285$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 3.053 | 0.01 | Nuffield Chemistry Boys |
| 1.1 Leisure interest | 3.607 | 0.001 | Nuffield Chemistry Boys |
| 1.2 As a method | 2.926 | 0.01 | Nuffield Chemistry Boys |
| 1.3 As facts | 0.292 | N.S. | |
| 1.31 Physics facts | 0.566 | N.S. | |
| 1.32 Biology facts | 0.866 | N.S. | |
| 1.33 Chemistry facts | 1.767 | N.S. | |
| 1.34 Astronomy facts | 0.288 | N.S. | |
| 1.35 Geology facts | 0.161 | N.S. | |
| 1.36 Science history facts | 0.108 | N.S. | |
| 2.0 Scientific thinking | 1.943 | N.S. | |
| 3.0 Attitude to school science | 2.113 | 0.05 | Nuffield Chemistry Boys |
| 4.0 Scientific ambition | 0.306 | N.S. | |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 2.911 | 0.01 | Nuffield Chemistry Boys |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 0.397 | N.S. | |
| 6.2 Literature | 1.043 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 2.131 | 0.05 | Nuffield Chemistry Boys |
| 7.2 Reading a book | 0.500 | N.S. | |
| 7.3 Asking a teacher | 0.909 | N.S. | |

table 12. Comparisons between boys taking Nuffield Physics and boys taking Traditional Science.

Nuffield Physics Boys $N_1 = 170$ Traditional Boys $N_2 = 285$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 2.812 | 0.01 | Traditional Boys |
| 1.1 Leisure interest | 3.725 | 0.001 | Traditional Boys |
| 1.2 As a method | 0.489 | N.S. | |
| 1.3 As facts | 2.678 | 0.01 | Traditional Boys |
| 1.31 Physics facts | 3.079 | 0.01 | Traditional Boys |
| 1.32 Biology facts | 0.752 | N.S. | |
| 1.33 Chemistry facts | 3.518 | 0.001 | Traditional Boys |
| 1.34 Astronomy facts | 0.788 | N.S. | |
| 1.35 Geology facts | 3.438 | 0.001 | Traditional Boys |
| 1.36 Science history facts | 0.260 | N.S. | |
| 2.0 Scientific thinking | 0.441 | N.S. | |
| 3.0 Attitude to school science | 2.705 | 0.01 | Traditional Boys |
| 4.0 Scientific ambition | 0.854 | N.S. | |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 2.807 | 0.01 | Traditional Boys |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.203 | 0.05 | Nuffield Physics Boys |
| 6.2 Literature | 2.774 | 0.01 | Nuffield Physics Boys |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.357 | N.S. | |
| 7.2 Reading a book | 3.995 | 0.001 | Traditional Boys |
| 7.3 Asking a teacher | 2.219 | 0.05 | Traditional Boys |

table 13. Comparisons between girls taking Nuffield Science and girls taking Traditional Science.

Nuffield Girls $N_1$ = 210 Traditional Girls N = 261

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 3.809 | 0.001 | Nuffield Girls |
| 1.1 Leisure interest | 2.979 | 0.01 | Nuffield Girls |
| 1.2 As a method | 3.626 | 0.001 | Nuffield Girls |
| 1.3 As facts | 2.358 | 0.02 | Nuffield Girls |
| 1.31 Physics facts | 2.129 | 0.05 | Nuffield Girls |
| 1.32 Biology facts | 1.686 | N.S. | |
| 1.33 Chemistry facts | 2.407 | 0.02 | Nuffield Girls |
| 1.34 Astronomy facts | 2.246 | 0.05 | Nuffield Girls |
| 1.35 Geology facts | 1.614 | N.S. | |
| 1.36 Science history facts | 0.975 | N.S. | |
| 2.0 Scientific thinking | 3.846 | 0.001 | Nuffield Girls |
| 3.0 Attitude to school science | 3.488 | 0.001 | Nuffield Girls |
| 4.0 Scientific ambition | 4.729 | 0.001 | Nuffield Girls |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 4.413 | 0.001 | Nuffield Girls |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.204 | 0.05 | Traditional Girls |
| 6.2 Literature | 0.313 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.855 | N.S. | |
| 7.2 Reading a book | 1.875 | N.S. | |
| 7.3 Asking a teacher | 3.064 | 0.01 | Traditional Girls |

table 14. Comparisons between girls taking Nuffield Biology and girls taking Traditional Science.

Nuffield Biology Girls $N_1$ = 119 Traditional Girls $N_2$ = 261

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 0.237 | N.S. | |
| 1.1 Leisure interest | 0.753 | N.S. | |
| 1.2 As a method | 1.625 | N.S. | |
| 1.3 As facts | 0.775 | N.S. | |
| 1.31 Physics facts | 0.530 | N.S. | |
| 1.32 Biology facts | 0.099 | N.S. | |
| 1.33 Chemistry facts | 0.309 | N.S. | |
| 1.34 Astronomy facts | 0.593 | N.S. | |
| 1.35 Geology facts | 0.342 | N.S. | |
| 1.36 Science history facts | 1.323 | N.S. | |
| 2.0 Scientific thinking | 2.231 | 0.05 | Nuffield Biology Girls |
| 3.0 Attitude to school science | 1.364 | N.S. | |
| 4.0 Scientific ambition | 2.109 | 0.05 | Nuffield Biology Girls |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 1.296 | N.S. | |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 0.604 | N.S. | |
| 6.2 Literature | 0.596 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.879 | N.S. | |
| 7.2 Reading a book | 2.487 | 0.02 | Traditional Girls |
| 7.3 Asking a teacher | 2.554 | 0.02 | Traditional Girls |

table 15. Comparisons between girls taking Nuffield Chemistry and girls taking Traditional Science.

Nuffield Chemistry Girls $N_1 = 52$ Traditional Girls $N_2 = 261$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 4.188 | 0.001 | Nuffield Chemistry Girls |
| 1.1 Leisure interest | 3.415 | 0.001 | Nuffield Chemistry Girls |
| 1.2 As a method | 3.384 | 0.001 | Nuffield Chemistry Girls |
| 1.3 As facts | 3.123 | 0.01 | Nuffield Chemistry Girls |
| 1.31 Physics facts | 1.762 | N.S. | |
| 1.32 Biology facts | 3.298 | 0.001 | Nuffield Chemistry Girls |
| 1.33 Chemistry facts | 2.201 | 0.05 | Nuffield Chemistry Girls |
| 1.34 Astronomy facts | 2.912 | 0.01 | Nuffield Chemistry Girls |
| 1.35 Geology facts | 1.901 | N.S. | |
| 1.36 Science history facts | 0.326 | N.S. | |
| 2.0 Scientific thinking | 2.588 | 0.01 | Nuffield Chemistry Girls |
| 3.0 Attitude to school science | 2.407 | 0.02 | Nuffield Chemistry Girls |
| 4.0 Scientific ambition | 3.072 | 0.01 | Nuffield Chemistry Girls |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 3.704 | 0.001 | Nuffield Chemistry Girls |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 0.512 | N.S. | |
| 6.2 Literature | 0.148 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.881 | N.S. | |
| 7.2 Reading a book | 0.107 | N.S. | |
| 7.3 Asking a teacher | 1.234 | N.S. | |

table 16. Comparisons between girls taking Nuffield Physics and girls taking Traditional Science.

Nuffield Physics Girls $N_1 = 39$ Traditional Girls $N_2 = 261$

| Variable | Significance Ratio | P | In Favour Of:- |
|---|---|---|---|
| SCIENTIFIC | | | |
| 1.0 Interest in science | 6.716 | 0.001 | Nuffield Physics Girls |
| 1.1 Leisure interest | 6.423 | 0.001 | Nuffield Physics Girls |
| 1.2 As a method | 4.286 | 0.001 | Nuffield Physics Girls |
| 1.3 As facts | 5.065 | 0.001 | Nuffield Physics Girls |
| 1.31 Physics facts | 4.415 | 0.001 | Nuffield Physics Girls |
| 1.32 Biology facts | 1.281 | N.S. | |
| 1.33 Chemistry facts | 5.010 | 0.001 | Nuffield Physics Girls |
| 1.34 Astronomy facts | 5.283 | 0.001 | Nuffield Physics Girls |
| 1.35 Geology facts | 2.141 | 0.05 | Nuffield Physics Girls |
| 1.36 Science history facts | 0.124 | N.S. | |
| 2.0 Scientific thinking | 3.651 | 0.001 | Nuffield Physics Girls |
| 3.0 Attitude to school science | 5.516 | 0.001 | Nuffield Physics Girls |
| 4.0 Scientific ambition | 5.036 | 0.001 | Nuffield Physics Girls |
| 5.0 Science orientation (S.O.) (1.0 + 2.0 + 3.0) | 6.366 | 0.001 | Nuffield Physics Girls |
| NON SCIENTIFIC | | | |
| 6.0 Non-science interests | | | |
| 6.1 Fine art | 2.349 | 0.02 | Traditional Girls |
| 6.2 Literature | 0.394 | N.S. | |
| 7.0 Interest in solving problems by appeal to authority | | | |
| 7.1 Consulting expert | 0.459 | N.S. | |
| 7.2 Reading a book | 0.526 | N.S. | |
| 7.3 Asking a teacher | 2.351 | 0.02 | Traditional Girls |

Examination of tables 4 to 16 shows a number of significant trends, and some are described below.

Before considering Nuffield and Traditional groups as such, attention is drawn to differences between attitudes and interests of boys and girls in the overall sample. The differences are consistent with previous research, indicating as they do a significantly greater over-all scientific orientation amongst boys than amongst girls; boys having greater interest, a better attitude to science as a school subject and more ambition to continue further scientific studies (7). The pattern of boys being more interested in the content of physics and chemistry and girls in the descriptive subjects biology, geology and history of science was expected and is also consistent with previous research (8). The corollary that girls show greater interest in non-scientific areas such as literature and fine-art was also re-confirmed (9). The somewhat unexpected absence of significant differences between boys and girls in interest in science as a method of solving problems or in scientific thinking (attitude) is noted. Of the three possible ways of solving problems by appeal to authority; that is by consulting an expert, reading a book or questioning a teacher, only the latter method proved significantly different between boys and girls and was in favour of girls.

Turning now to comparisons between Nuffield and Traditional programmes, table 5 shows highly significant gains by Nuffield pupils in over-all scientific orientation; including especially significant gains in interest in science as a method of solving problems, in scientific thinking and in ambition to pursue further studies of science later. There were less highly signficant gains in attitudes towards science as a leisure-time activity, but the absence of significant differences between Nuffield and Traditional pupils in their interests in the facts of science, either as a whole or for individual disciplines, is noted with some concern. The implications of this are considered below (see discussion). Of the two non-science leisure activities, fine art and literature, only differences in interest in the former proved significant with preference for Fine Art amongst Traditional pupils.

Pupils taking Traditional courses showed significantly greater interest than Nuffield pupils in solving problems by reading or by asking teachers but there was no difference between the two groups in preference for solving problems by consulting experts. The strong preference by Nuffield pupils to

solve problems empirically and for Traditional pupils to do so by appeal to authoritative sources has urgent educational implications and these are considered in the discussion.

When each of the three O-level subjects Biology, Chemistry and Physics was considered separately, highly contrasted patterns were obtained from subject to subject. The three programmes were by no means equally successful in developing significant gains in attitude and interest.

Nuffield Chemistry, it is noted, was most successful, biology less successful and physics generally unsuccessful in promoting positive attitudinal changes towards science and science teaching. Nuffield Chemistry showed significant gains over Traditional Chemistry in almost all the dimensions of scientific attitude and interest except interest in the factual content of sciences other than physics and chemistry. This lack of transfer to other branches of science is of relevance to a general consideration of the over-all effectiveness of the Nuffield programmes (see discussion). Students taking Nuffield Chemistry were significantly less interested in fine art and literature and showed less willingness to consult their science teachers on problems than did pupils taking Traditional programmes.

Pupils taking Nuffield Biology showed no significant gain in over-all scientific orientation but did gain in terms of interest in science as a method of investigation, and also in interest in biological facts. There was no gain however, in interest in other branches of science. Gains in scientific thinking and in an ambition to study more science later are noted. Nuffield Biology pupils, however, showed less preference for solving problems by reading or by questioning the teacher than their contemporaries in traditional courses.

The over-all results for Nuffield Physics showed a significant gain for Nuffield on only one variable - ambition to study more science later. A greater interest in the facts of biology and geology by students taking traditional physics is also noted.

This over-all pattern and the pattern for each discipline changed considerably when boys and girls were considered separately (tables 9 to 16).

The striking difference between tables 9 (boys) and 13 (girls) is of special significance. With the boys, Nuffield science, in overall impact, does not show any significant gain over traditional programmes in any of the twenty variables measured whereas with girls there are significant gains on eleven of the fourteen science biased attitudinal dimensions (variables 1.0 to 4.0).

Tables 10 and 11 show some gains with boys taking Nuffield Biology and Chemistry, but Nuffield Physics in the sample studied, seems to have caused a reverse reaction. There are no effective gains amongst Nuffield Physics boys except in literary and artistic interests but there are significant gains by pupils taking traditional programmes in eight of the fourteen science-biased attitudinal variables including interest in the factual content of physics itself!

Girls on the other hand seem to have benefited very significantly and it is the gains made by girls rather than by boys that contribute to the apparent over-all success of the Nuffield programmes shown in tables 5,6 and 7. The exception is for biology (table 14). More gains in this subject were made by boys (table 10) than girls (table 14) but both boys and girls taking Nuffield Biology showed better scientific thinking and greater ambition to study more science than their counterparts studying Traditional programmes.

The most dramatic successes were with girls taking Nuffield Chemistry and Nuffield Physics (tables 15 and 16) with the former making significant gains on at least eleven out of fourteen science-biased attitudinal dimensions. The failure, however, to promote gains in interest in the factual content of certain branches of science such as physics and geology (by chemistry girls), biology (by physics girls) and history of science (by both these groups), is noted with some concern.

## DISCUSSION

Seven major conclusions seem to emerge from this study.

1. The most important conclusion appears to be that by 1966 the trial materials of the Nuffield Science Programmes for 'O'-level G.C.E. had had only limited success in improving scientific attitudes and interests of boys. They had marked success, however, in improving the attitudes of girls.

   This finding we generally confirmed by analysis of essays and interviews. From these qualitative data also emerged the following hypothesis. Girls taking traditional science courses were subjected to the usual social pressures working to produce lack of interest in scientific things and poor attitudes to science (10 - also see data in table 4). For the girls in the Nuffield Programme many of these traditional influences were counteracted by the special interest taken in science by the school authorities. The dramatic improvements noted in this study seem to be a response by girls to the flattery, to use the words of one pupil, "of being thought important enough to be a guinea pig in an experiment in science education", rather than as a response to the course as such. This hypothesis is strengthened by the finding that most of the gains were made by girls taking Nuffield Chemistry or Nuffield Physics. Girls taking Nuffield Biology made few gains. Biology has always been a popular and well-liked subject with girls (11). By contrast boys taking Nuffield Biology gained more than the girls (tables 10 & 14). Boys have always tended to be less interested in biology than girls. It seems that significant differences were obtained mainly be groups who had, traditionally, little interest in their science courses. This of course is a most important and worthwhile achievement, but it cannot be clearly and unambiguously established from this study that the improvement was due to the Nuffield philosophy and materials. It could have been due to unusual, special personal attention given by teachers to relatively indifferent pupils who would not in the ordinary course of events have been given such close attention by teachers of traditional courses.

2. For most groups Nuffield Science courses tended to increase interest in empiricism and in science as a leisure activity. With the exception of girls taking Nuffield Physics and Chemistry there was no significant improvement, however, in interest in the factual content of the sciences studied. This lack of improved interest in the facts of science was especially noticeable amongst the boys. It appears as though the Nuffield philosophy has tended to swing the pendulum a little too far from the "fact centred" approach to the "problem centred" approach without 'building-in" suitable safe-guards. Pupils interviewed, especially boys, seemed to feel almost guilty saying they liked the facts included in their courses. They had been over-trained to show interest in problem-solving and to be hypercritical of even generally accepted scientific facts. Perhaps this is a healthy counter to the admitted over-emphasis on "facts for facts sake" prevalent in past teaching. There is, however, the danger of increasing cynicism and doubt about the value of our cultural heritage and hence even of the values of our whole social order if this objective is over-emphasised at the expense of other objectives. Of course a certain amount of cynicism is healthy, especially in science; but this must be developed alongside a respect for past achievement and an understanding and appreciation at the vast resource of knowledge that man has accumulated during his past 30,000 years.

3. Even where the Nuffield materials did improve interest of some sub-groups in the factual content of a particular discipline, this interest rarely transferred to other disciplines. This point is made clear if the following extracts from the inter-correlation matrices reported in the Appendix are compared (see table 17).

table 17. Inter-correlations of Interest in the Factual Content of Six Branches of Science.

(A) Traditional Pupils

| | Biology | Chemistry | Astronomy | Geology | Science History |
|---|---|---|---|---|---|
| Physics | .073 | .695 | .287 | .195 | -.015 |
| Biology | | .214 | .077 | .178 | .060 |
| Chemistry | | | .235 | .223 | -.017 |
| Astronomy | | | | .484 | .256 |
| Geology | | | | | .264 |

(B) Nuffield Pupils

| | Biology | Chemistry | Astronomy | Geology | Science History |
|---|---|---|---|---|---|
| Physics | .260 | .727 | .322 | .150 | .075 |
| Biology | | .353 | .145 | .283 | .184 |
| Chemistry | | | .243 | .193 | .111 |
| Astronomy | | | | .385 | .227 |
| Geology | | | | | .269 |

With one or two exceptions increases due to Nuffield courses in the interest correlations between pairs of disciplines were not of any worthwhile magnitude. A particularly disturbing feature is that Nuffield materials were unable to significantly overcome the traditionally low correlation between interest in the content of science subjects and interest in the history of science. A modern programme of science education should surely have as a major objective, a developing awareness of how science progresses and how it builds to contribute to a further understanding of our environment. The Nuffield trial materials seemed not to have achieved this objective. Similarly there remained the traditionally low correlations between interest in quantitative science (physics and chemistry) and more descriptive science

(biology and geology). A more general criticism, however, is that even improved interest in one area of scientific fact does not seem to transfer at all successfully to another area of scientific fact, much less to areas outside science. The implications for the general educational contributions of the programmes are obvious.

Transfer of interest in facts, is admittedly more difficult to attain than transfer of interests in procedure or method which are, after all, common to most sciences. Nevertheless interviews with pupils and examination of course materials, revealed little evidence of a genuine attempt at bridge-building. Physics was taught strictly within a physical "frame of reference" and so on; and there seemed little emphasis on the unity or universality of science.

4. Probably even more serious than the lack of transfer of increased interest from science discipline to science discipline was the existence of a negative transfer to other areas of the curriculum. Rather too many Nuffield sub-groups showed significant decline in interest in fine art or literature. This was true, for example, in the case of many of the Nuffield Chemistry pupils (table 7). This suggests that the relative significance and place of science in our general culture may have been over-emphasised at the expense of courses stressing other equally important values.

5. The failure of the Nuffield Physics trial materials to improve the interests and attitudes of boys (table 12) requires further discussion. The reaction of the 170 boys in the sample was negative. At first one is inclined to suspect the sample, but while this was small it was fairly representative in that the pupils came from four widely separated schools and there were seven different classes each taught by a different master. If this sample is at all representative then the trial editions of the Nuffield Physics, as they were presented to boys in this study, require re-assessment. Not only did they fail to increase relevant scientific attitudes and interests but they actually caused pupils to be less favourably disposed towards many aspects, than equivalent pupils in traditional courses. Further increased interest in literature and fine art, at first thought a most welcome positive gain, represented more a retreat from science than an advance towards the Arts. The totally reverse influence of this course on the small

numbers of girls in this study has already been noted and may be explained by a response to improved status as discussed above. It may well be that these contrasted and disturbing patterns would disappear with a more thorough investigation of larger populations using the final version of the materials. Nevertheless there seems sufficient evidence here to suggest there may be fundamental weaknesses in the conceptual basis of the Nuffield Physics programme. Information from interviews provides some hypotheses about the Physics course for further study. These hypotheses are as follows:

(a) there is an over-emphasis on empirical investigation at the expense of other objectives.

(b) the course is too hard for the average G.C.E. pupil.

(c) concepts which provide unsuitable material for problem-solving or inquiry teaching, are forced into "problem settings". Intelligent pupils therefore claim the course is "pseudo-scientific" and less able pupils find it long-drawn-out, boring and difficult.

(d) the sequential development is too rigid and there is insufficient opportunity for individualized learning.

(e) the course while intellectual, delightful and challenging for professional physicists is too academic and unreal for the average schoolboy. It is unrelated to the pupil's personal social environment.

It should be further emphasised that these ideas are presented only as hypotheses for further testing, but with the worrying findings of the Dainton Report at hand, it would be tragic to introduce courses presented as models of curriculum excellance, which have the effect of <u>increasing</u> the drift from the sciences. It is imperative that the reasons for the data in table 12 be identified and counteracted as quickly as possible.

6. An emphasis on "inquiry" or "problem solving" and "direct experience" is an important aspect of modern science curricula. Inquiry teaching is an essential element in the development of divergent thinking, creativity and lasting learning. There was some suggestion however, from interviews and observation of lessons that this has been over-emphasised or interpreted too narrowly by some teachers using the Nuffield trial materials, and perhaps

even by the authors, especially in Physics.

As discussed in 2 above, evidence from this study suggests that the Nuffield trial materials gave an increased interest in solving problems by direct experience. There is, however, a danger that methods other than direct experience will become held in contempt even when empiricism is impracticable or inappropriate in a learning situation. The very frequent decline in interest shown by several Nuffield sub-groups in this study in solving problems by consulting authorative sources such as books and journals or by simply questioning the teacher, is alarming. An important objective of science teaching should surely be to train pupils in data retrieval so they can quickly and critically gather together information already know to science which may provide answers to problems. The lack of willingness to solve problems by questioning the teacher is particularly disturbing. It points to teachers as being discarded as useful resources in the classroom with a subsequent weakening of those teacher-pupil bonds that are essential for a good classroom climate. One pupil commented "everytime I ask our science teacher a question he answers by asking me another - so I don't talk much to him now and I don't like him watching me in the laboratory". This is a fair comment and a warning. "Discovery" in the classroom doesn't necessarily always mean "empirical discovery" by direct experience but many teachers, especially physics teachers, tended to teach the Nuffield trial materials only in this way.

.7. An important aspect of the results is that in spite of some of the weaknesses and problems considered above, the over-all effect of the Nuffield materials has been to improve scientific thinking (table 5 variable 2.0). This gain was achieved in the sample studied by both boys and girls taking the Nuffield courses in Biology and by girls taking each of the three Nuffield sciences. This finding, incidentally, is in general terms, consistent with recent work by Laughton and Wilkinson (12). These workers compared the scientific thinking of 233 pupils taking Nuffield and traditional programmes for G.C.E. in English Grammar Schools and found no significant difference between the groups for the older boys, but highly significant differences for the older girls in favour of Nuffield.

The tentative nature of conclusions from this study must be emphasised. They are tentative for a number of reasons. Firstly the population, especially of girls taking Nuffield Chemistry and Physics, was small. Secondly the work was completed in 1966 when pupils were using only trial editions. While basic philosophy remains unchanged there have been many changes of specific content in the final editions of the materials published since 1966. Thirdly, the pupils tested were amongst the first to be taught these materials and the teachers were learning almost as much as the pupils. Many of the results of this study must have been determined by the way teachers interpreted the content and intent of the Nuffield programme. Fourthly the attitude/interest tests used in this study were not specifically designed to test for achievement of the precise objectives of the Nuffield programmes. More specific instruments should be developed to provide measures of more closely specified affective variables.

All this report can do is raise questions and problems for further investigation by subsequent workers. These workers should be able to use more reliable samples after the courses have become reasonably well established. They should then be able to develop more precise instruments to measure the variables concerned.

ACKNOWLEDGEMENTS

In 1966 The Nuffield Foundation made available a Special Study Grant for an investigation into aspects of the Nuffield Science teaching programme in England. This support is gratefully acknowledged. The direct and personal assistance of Mr. Brian Young is deeply appreciated. The staff and various people working on the Science Teaching Project itself, both at Project Headquarters and in schools, were most generous with their time and help. I am particularly grateful to Professor K.W. Keohane, Mr. John Maddox, Dr. G. Van Praagh and Mr. Peter Kelly who gave valuable professional advice.

I would also like to thank the University of London Institute of Education for welcoming me to the staff as a Visiting Scholar and for extending professional assistance. In particular Mrs. D. Penfold, Dr.J. Clarke and Dr. D. Dale of the Institute gave direct professional assistance and I am very grateful to them. Mr. Richard Barnes, also of the London Institute, administered many of the tests and interviews and this most valuable help is gratefully acknowledged.

Some of the statistical calculations were undertaken by computer with the assistance of staff of the National Foundation for Educational Research and Mr. Brian E. Cooper of the Science Research Council Atlas Computer Laboratory. Later, in Australia, all statistical calculations were finalized and checked with the assistance of Mr. Robert Watts and Miss Anne Watts and the help of these people and institutions is acknowledged and greatly appreciated.

Finally I would like to thank all the principals, teachers and pupils who answered questions and undertook tests. Their willing and kindly cooperation made it possible to complete this study.

## STATISTICAL APPENDIX

I. Inter-correlations of twenty variables measured in the survey:

A. Pupils taking Traditional Science
B. Pupils taking Nuffield Science.

II. Means and Standard Deviations of nineteen variables for all pupils and for the following sub-groups in the survey:

## STATISTICAL APPENDIX

Inter-Correlations of 20 Variables - Traditional Science.

| | Science Orientation (5.0) | Interest In Science (1.0) | Leisure Interest(1.1) | As A Method (1.2) | As Facts (1.3) | Physics Facts (1.31) | Biology Facts (1.32) | Chemistry Facts (1.33) | Astronomy Facts (1.34) | Geology Facts (1.35) | Science History Facts (1.36) | Fine Art (6.1) | Literature (6.2) | Consulting Expert (7.1) | Reading A Book (7.2) | Asking A Teacher (7.3) | Scientific Thinking (2.0) | Attitude To School Science (3.0) | Scientific Ambition + (4.0) | Sex • |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Science Orientation (5.0) | — | .860 | .785 | .598 | .661 | .583 | .356 | .706 | .367 | .281 | .061 | .183 | -.116 | .142 | .187 | .000 | .631 | .889 | .557 | .222 |
| Interest In Science(1.0) | .860 | — | .822 | .799 | .743 | .585 | .352 | .677 | .472 | .401 | .167 | -.100 | -.013 | .253 | .184 | .002 | .457 | .579 | .448 | .221 |
| Leisure Interest(1.1) | .785 | .822 | — | .400 | .509 | .587 | .118 | .665 | .313 | .178 | -.001 | -.293 | -.199 | .179 | .173 | .074 | .343 | .632 | .530 | .394 |
| As A Method (1.2) | .598 | .799 | .400 | — | .423 | .256 | .328 | .352 | .270 | .261 | .052 | .058 | .108 | .177 | .023 | -.156 | .360 | .302 | .229 | .021 |
| As Facts (1.3) | .661 | .744 | .509 | .423 | — | .612 | .462 | .655 | .647 | .641 | .482 | .042 | .101 | .277 | .307 | .145 | .405 | .444 | .290 | .083 |
| Physics Facts (1.31) | .583 | .585 | .588 | .256 | .612 | — | .073 | .695 | .287 | .[illegible]5 | -.015 | -.273 | -.258 | .182 | .142 | .058 | .269 | .484 | .417 | .414 |
| Biology Facts (1.32) | .356 | .352 | .118 | .328 | .462 | .073 | — | .214 | .077 | .178 | .060 | .230 | .194 | .150 | .220 | .134 | .200 | .286 | .151 | -.258 |
| Chemistry Facts (1.33) | .706 | .677 | .656 | .352 | .655 | .[illegible]5 | .214 | — | .235 | .223 | -.017 | -.251 | -.187 | .155 | .125 | .060 | .315 | .618 | .535 | .294 |
| Astronomy Facts (1.34) | .367 | .472 | .313 | .270 | .647 | .287 | .077 | .235 | — | .484 | .256 | .056 | .041 | .187 | .212 | .072 | .265 | .181 | .096 | .079 |
| Geology Facts (1.35) | .281 | .401 | .178 | .260 | .641 | .194 | .178 | .223 | .484 | — | .26[illegible] | .124 | .120 | .129 | .172 | .091 | .250 | .090 | .004 | .017 |
| Science History Facts (1.36) | .061 | .167 | -.001 | .053 | .481 | -.015 | .060 | -.017 | .256 | .264 | — | .221 | .368 | .180 | .169 | .094 | .146 | -.082 | -.151 | -.173 |
| Fine Art(6.1) | -.183 | -.100 | -.293 | .058 | .041 | -.273 | .229 | -.251 | .056 | .124 | .221 | — | .440 | .168 | .107 | .141 | .006 | -.256 | -.311 | -.439 |
| Literature (6.2) | -.116 | -.013 | -.199 | .108 | .101 | -.258 | .194 | -.187 | .041 | .120 | .368 | .440 | — | .153 | .331 | .133 | .115 | -.243 | -.303 | -.422 |
| Consulting Expert (7.1) | .141 | .253 | .179 | .177 | .277 | .182 | .150 | .155 | .187 | .129 | .180 | .168 | .153 | — | .202 | .376 | .077 | .021 | .021 | -.016 |
| Reading A Book (7.2) | .187 | .184 | .173 | .023 | .307 | .142 | .220 | .125 | .212 | .172 | .169 | .107 | .331 | .202 | — | .364 | .180 | .126 | .062 | -.038 |
| Asking A Teacher(7.3) | .000 | .002 | .074 | -.156 | .145 | .058 | .134 | .060 | .072 | .091 | .094 | .141 | .133 | .376 | .364 | — | -.058 | .022 | .034 | -.145 |
| Scientific Thinking (2.0) | .631 | .457 | .343 | .360 | .405 | .269 | .200 | .315 | .265 | .250 | .146 | .006 | .115 | .077 | .180 | -.058 | — | .413 | .266 | .052 |
| Attitude To School Science(3.0) | .889 | .579 | .632 | .302 | .444 | .484 | .285 | .618 | .181 | .090 | -.083 | -.256 | -.243 | .020 | .126 | .022 | .413 | — | .553 | .206 |
| Scientific Ambition + (4.0) | .557 | .448 | .530 | .229 | .290 | .417 | .151 | .535 | .095 | .004 | -.151 | -.311 | -.303 | .021 | .062 | -.034 | .266 | .553 | — | -.355 |
| Sex • | .222 | .221 | .394 | .021 | .083 | .414 | -.258 | .294 | .079 | .017 | -.173 | -.439 | -.422 | -.016 | -.038 | -.145 | .052 | .206 | -.355 | — |

+ = Biserial in favour of taking Science in 6th Form. • = Biserial in favour of boys.

## STATISTICAL APPENDIX

**Inter-Correlations of 20 Variables - Nuffield Science.**

| | Science Orientation (5.0) | Interest In Science (1.0) | Leisure Interest (1.1) | As A Method (1.2) | As Facts (1.3) | Physics Facts (1.31) | Biology Facts (1.32) | Chemistry Facts (1.33) | Astronomy Facts (1.34) | Geology Facts (1.35) | Science History Facts (1.36) | Fine Art (6.1) | Literature (6.2) | Consulting Expert (7.1) | Reading A Book (7.2) | Asking A Teacher (7.3) | Scientific Thinking (2.0) | Attitude To School Science (3.0) | Scientific Ambition + (4.0) | Sex * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Science Orientation (5.0)** | — | .890 | .840 | .636 | .688 | .634 | .433 | .745 | .373 | .223 | .152 | -.168 | -.120 | .176 | .244 | .019 | .699 | .909 | .617 | .020 |
| **Interest In Science (1.0)** | .890 | — | .861 | .802 | .770 | .634 | .463 | .711 | .448 | .355 | .254 | -.108 | -.018 | .274 | .303 | .023 | .528 | .667 | .494 | .039 |
| **Leisure Interest (1.1)** | .840 | .861 | — | .476 | .579 | .624 | .251 | .682 | .325 | .200 | .104 | -.242 | -.154 | .230 | .302 | .080 | .468 | .715 | .547 | .202 |
| **As A Method (1.2)** | .636 | .802 | .476 | — | .437 | .307 | .368 | .389 | .273 | .200 | .112 | -.002 | .022 | .192 | .146 | -.153 | .393 | .389 | .285 | -.075 |
| **As Facts (1.3)** | .688 | .769 | .579 | .437 | — | .671 | .601 | .710 | .385 | .274 | .506 | .035 | .134 | .272 | .314 | .173 | .441 | .507 | .353 | -.075 |
| **Physics Facts (1.31)** | .633 | .634 | .624 | .307 | .671 | — | .260 | .727 | .322 | .150 | .075 | -.223 | -.173 | .150 | .190 | .075 | .369 | .548 | .414 | .221 |
| **Biology Facts (1.32)** | .433 | .463 | .251 | .368 | .602 | .260 | — | .353 | .145 | .283 | .184 | .193 | .208 | .191 | .227 | .175 | .236 | .331 | .291 | -.279 |
| **Chemistry Facts (1.33)** | .745 | .711 | .682 | .389 | .710 | .727 | .353 | — | .243 | .193 | .111 | -.198 | -.131 | .195 | .237 | .088 | .450 | .668 | .551 | .123 |
| **Astronomy Facts (1.34)** | .373 | .448 | .325 | .273 | .585 | .322 | .145 | .243 | — | .385 | .227 | -.008 | .102 | .169 | .183 | .050 | .252 | .245 | .066 | -.082 |
| **Geology Facts (1.35)** | .223 | .355 | .200 | .200 | .574 | .150 | .283 | .193 | .385 | — | .269 | .148 | .182 | .169 | .225 | .121 | .143 | .069 | -.008 | -.135 |
| **Science History Facts (1.36)** | .152 | .254 | .104 | .112 | .507 | .075 | .184 | .111 | .227 | .269 | — | .206 | .341 | .191 | .195 | .130 | .145 | .019 | -.005 | -.138 |
| **Fine Art (6.1)** | -.168 | -.108 | -.242 | -.002 | .035 | -.223 | .193 | -.197 | -.008 | .148 | .206 | — | .403 | .107 | .034 | .068 | -.015 | -.224 | -.242 | -.289 |
| **Literature (6.2)** | -.120 | -.018 | -.154 | .022 | .134 | -.173 | .208 | -.130 | .102 | .182 | .341 | .403 | — | .209 | .206 | .168 | .026 | -.226 | -.189 | -.378 |
| **Consulting Expert (7.1)** | .176 | .274 | .230 | .192 | .272 | .150 | .191 | .194 | .169 | .169 | .191 | .107 | .209 | — | .324 | .408 | .111 | .066 | .076 | .039 |
| **Reading A Book (7.2)** | .244 | .303 | .302 | .146 | .314 | .190 | .227 | .237 | .183 | .225 | .105 | .034 | .206 | .324 | — | .352 | .147 | .161 | .109 | -.034 |
| **Asking A Teacher (7.3)** | .019 | .023 | .080 | -.153 | .173 | .075 | .175 | .088 | .050 | .121 | .130 | .068 | .168 | .408 | .352 | — | -.026 | .031 | .042 | -.078 |
| **Scientific Thinking (2.0)** | .699 | .528 | .468 | .393 | .441 | .369 | .236 | .450 | .252 | .143 | .145 | -.015 | .026 | .111 | .147 | -.026 | — | .525 | .367 | -.067 |
| **Attitude To School Science (3.0)** | .909 | .667 | .715 | .389 | .507 | .548 | .331 | .668 | .245 | .069 | .019 | -.224 | -.226 | .066 | .162 | .031 | .525 | — | .625 | .033 |
| **Scientific Ambition + (4.0)** | .617 | .494 | .547 | .285 | .353 | .414 | .290 | .551 | .066 | -.008 | -.005 | -.242 | -.189 | .076 | .109 | .042 | .367 | .625 | — | -.155 |
| **Sex *** | .020 | .039 | .202 | -.075 | -.075 | .221 | -.270 | .123 | -.082 | -.135 | -.135 | -.289 | -.378 | .039 | -.034 | -.078 | -.067 | .033 | -.155 | — |

\+ = Biserial in favour of taking Science in 6th Form. * = Biserial in favour of boys.

## STATISTICAL APPENDIX

Means and Standard Deviations of nineteen variables for all pupils and for various sub-groups in the survey. For identification of variables see table 3.

| Variable | All Pupils | | All Traditional | | All Nuffield | | All Boys | | All Girls | | Traditional Boys | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| 1.0 | 72.927 | 17.917 | 71.245 | 17.113 | 74.410 | 18.292 | 74.877 | 17.972 | 69.994 | 17.220 | 74.863 | 16.928 |
| 1.1 | 22.462 | 8.497 | 21.647 | 8.195 | 23.116 | 8.682 | 24.457 | 8.256 | 19.263 | 7.884 | 24.733 | 7.731 |
| 1.2 | 27.710 | 8.236 | 26.751 | 8.214 | 28.479 | 8.179 | 27.633 | 8.075 | 27.832 | 8.495 | 26.912 | 7.782 |
| 1.3 | 22.846 | 5.269 | 22.826 | 5.037 | 22.862 | 5.451 | 22.829 | 5.489 | 22.873 | 4.899 | 23.225 | 5.266 |
| 1.31 | 21.051 | 8.214 | 20.612 | 8.051 | 21.404 | 8.331 | 23.073 | 7.915 | 17.811 | 7.633 | 23.797 | 7.731 |
| 1.32 | 23.881 | 8.844 | 23.905 | 8.799 | 23.862 | 8.886 | 22.061 | 9.042 | 26.798 | 7.672 | 21.737 | 8.778 |
| 1.33 | 21.253 | 9.305 | 20.698 | 8.959 | 21.699 | 9.557 | 22.759 | 9.286 | 18.839 | 8.822 | 23.218 | 8.941 |
| 1.34 | 25.907 | 8.162 | 25.899 | 8.359 | 25.913 | 8.007 | 25.874 | 8.130 | 25.960 | 8.223 | 26.530 | 8.094 |
| 1.35 | 24.991 | 7.607 | 25.328 | 7.528 | 24.721 | 7.664 | 24.568 | 7.840 | 25.669 | 7.172 | 25.453 | 7.818 |
| 1.36 | 19.312 | 9.651 | 19.832 | 9.999 | 18.894 | 9.348 | 18.101 | 9.606 | 21.252 | 9.413 | 18.182 | 10.167 |
| 2.0 | 22.719 | 7.826 | 21.833 | 7.463 | 23.429 | 8.040 | 22.743 | 7.840 | 22.679 | 7.810 | 22.204 | 7.589 |
| 3.0 | 11.864 | 20.588 | 10.236 | 20.423 | 13.171 | 20.641 | 13.865 | 21.000 | 8.656 | 19.506 | 14.263 | 20.458 |
| 4.0 | 1.650 | 0.477 | 1.718 | 0.450 | 1.596 | 0.491 | 1.552 | 0.498 | 1.807 | 0.395 | 1.565 | 0.497 |
| 5.0 | 107.529 | 39.604 | 103.304 | 37.631 | 110.921 | 40.832 | 111.393 | 40.526 | 101.333 | 37.294 | 111.295 | 38.294 |
| 6.1 | 16.104 | 8.779 | 16.910 | 8.828 | 15.456 | 8.692 | 13.562 | 7.931 | 20.178 | 8.541 | 13.204 | 7.531 |
| 6.2 | 21.302 | 7.839 | 21.698 | 7.896 | 20.984 | 7.785 | 18.828 | 7.308 | 25.268 | 6.993 | 18.512 | 7.058 |
| 7.1 | 20.445 | 6.947 | 20.447 | 6.922 | 20.443 | 6.972 | 20.517 | 7.197 | 20.329 | 6.531 | 20.340 | 7.292 |
| 7.2 | 20.613 | 6.969 | 21.317 | 7.074 | 20.047 | 6.837 | 20.335 | 6.988 | 21.057 | 6.922 | 21.063 | 7.036 |
| 7.3 | 17.198 | 7.410 | 18.209 | 7.125 | 16.387 | 7.538 | 16.458 | 7.498 | 18.384 | 7.114 | 17.225 | 7.127 |

## STATISTICAL APPENDIX

Means and Standard Deviations of nineteen variables for all pupils and for various sub-groups in the survey (continued). For identification of variables see table 3.

| Variable | Nuffield Boys | | Traditional Girls | | Nuffield Girls | | All Nuffield Biology | | All Nuffield Chemistry | | All Nuffield Physics | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| 1.0 | 74.885 | 18.594 | 67.295 | 16.458 | 73.348 | 17.593 | 71.888 | 17.928 | 79.077 | 15.424 | 72.493 | 20.527 |
| 1.1 | 24.289 | 8.562 | 18.276 | 7.324 | 20.491 | 8.386 | 20.940 | 8.550 | 26.086 | 7.414 | 22.579 | 9.221 |
| 1.2 | 28.070 | 8.224 | 26.575 | 8.671 | 29.395 | 8.019 | 28.520 | 8.204 | 29.344 | 7.246 | 27.517 | 8.973 |
| 1.3 | 22.589 | 5.613 | 22.391 | 4.746 | 23.471 | 5.030 | 22.396 | 5.256 | 23.692 | 4.825 | 22.541 | 6.181 |
| 1.31 | 22.634 | 8.000 | 17.134 | 6.880 | 18.652 | 8.417 | 19.660 | 8.272 | 23.072 | 7.683 | 21.727 | 8.691 |
| 1.32 | 22.258 | 9.202 | 26.272 | 8.208 | 27.452 | 6.912 | 25.864 | 7.901 | 23.072 | 8.776 | 22.301 | 9.677 |
| 1.33 | 22.481 | 9.488 | 17.946 | 8.147 | 19.948 | 9.499 | 20.436 | 9.645 | 23.855 | 8.685 | 20.928 | 9.977 |
| 1.34 | 25.477 | 8.134 | 25.211 | 8.602 | 26.891 | 7.645 | 24.264 | 7.764 | 26.851 | 7.685 | 26.894 | 8.335 |
| 1.35 | 24.032 | 7.814 | 25.192 | 7.211 | 26.262 | 7.096 | 24.512 | 7.702 | 25.973 | 7.485 | 23.646 | 7.654 |
| 1.36 | 18.051 | 9.259 | 21.632 | 9.509 | 20.781 | 9.293 | 19.176 | 9.321 | 18.787 | 9.622 | 18.670 | 9.121 |
| 2.0 | 23.070 | 7.980 | 21.429 | 7.317 | 24.233 | 8.136 | 23.696 | 8.053 | 23.833 | 7.507 | 22.684 | 8.542 |
| 3.0 | 13.623 | 21.340 | 5.839 | 19.492 | 12.157 | 18.995 | 11.724 | 20.728 | 16.977 | 18.030 | 10.876 | 22.569 |
| 4.0 | 1.545 | 0.499 | 1.885 | 0.320 | 1.710 | 0.455 | 1.604 | 0.490 | 1.602 | 0.491 | 1.579 | 0.495 |
| 5.0 | 111.453 | 41.862 | 94.579 | 34.930 | 109.729 | 38.499 | 107.308 | 40.261 | 119.887 | 34.604 | 105.761 | 45.911 |
| 6.1 | 13.779 | 8.164 | 20.958 | 8.359 | 19.210 | 8.684 | 15.848 | 8.535 | 15.113 | 9.082 | 15.349 | 8.479 |
| 6.2 | 19.019 | 7.457 | 25.176 | 7.280 | 25.381 | 6.636 | 21.996 | 7.760 | 19.552 | 7.749 | 21.287 | 7.666 |
| 7.1 | 20.623 | 7.145 | 20.563 | 6.506 | 20.038 | 6.566 | 19.864 | 7.355 | 21.272 | 6.639 | 20.258 | 6.792 |
| 7.2 | 19.894 | 6.929 | 21.594 | 7.117 | 20.391 | 6.628 | 19.980 | 6.527 | 21.403 | 6.243 | 18.694 | 7.520 |
| 7.3 | 15.994 | 7.685 | 19.284 | 6.979 | 17.267 | 7.138 | 16.520 | 7.511 | 16.914 | 6.867 | 15.670 | 8.199 |

## STATISTICAL APPENDIX

Means and Standard Deviations of nineteen variables for all pupils and for various sub-groups in the survey (continued). For identification of variables see table 3.

| Variable | Nuffield Biology Boys | | Nuffield Chemistry Boys | | Nuffield Physics Boys | | Nuffield Biology Girls | | Nuffield Chemistry Girls | | Nuffield Physics Girls | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| 1.0 | 75.657 | 18.069 | 79.610 | 15.389 | 69.591 | 20.543 | 67.740 | 16.895 | 77.346 | 15.560 | 85.128 | 15.104 |
| 1.1 | 23.931 | 8.288 | 27.284 | 6.978 | 21.588 | 9.263 | 17.647 | 7.598 | 22.192 | 7.517 | 26.897 | 7.766 |
| 1.2 | 28.878 | 7.912 | 29.024 | 7.304 | 26.500 | 9.090 | 28.126 | 8.530 | 30.385 | 7.024 | 31.949 | 6.962 |
| 1.3 | 22.771 | 5.694 | 23.361 | 4.729 | 21.682 | 6.229 | 21.983 | 4.717 | 24.770 | 5.020 | 26.282 | 4.347 |
| 1.31 | 22.351 | 8.053 | 24.120 | 6.959 | 21.300 | 8.679 | 16.698 | 7.486 | 19.423 | 8.795 | 23.590 | 8.605 |
| 1.32 | 25.420 | 8.768 | 21.024 | 8.361 | 21.047 | 9.777 | 26.353 | 6.825 | 29.731 | 6.544 | 27.770 | 7.047 |
| 1.33 | 22.970 | 9.612 | 24.681 | 8.175 | 19.918 | 10.035 | 17.647 | 8.918 | 21.173 | 9.779 | 25.333 | 8.517 |
| 1.34 | 23.870 | 8.117 | 26.308 | 7.694 | 25.888 | 8.438 | 24.698 | 7.366 | 28.615 | 7.458 | 31.282 | 6.274 |
| 1.35 | 23.641 | 7.841 | 25.568 | 7.542 | 22.806 | 7.849 | 25.471 | 7.462 | 27.289 | 7.212 | 27.308 | 5.454 |
| 1.36 | 18.152 | 9.671 | 18.077 | 9.153 | 17.947 | 9.092 | 20.303 | 8.824 | 21.096 | 10.784 | 21.821 | 8.669 |
| 2.0 | 23.970 | 7.928 | 23.603 | 7.341 | 21.847 | 8.508 | 23.395 | 8.211 | 24.577 | 8.055 | 26.333 | 7.791 |
| 3.0 | 14.443 | 21.991 | 18.219 | 17.525 | 8.424 | 23.185 | 8.731 | 18.886 | 12.942 | 19.207 | 21.564 | 15.912 |
| 4.0 | 1.420 | 0.495 | 1.580 | 0.495 | 1.606 | 4.901 | 1.807 | 0.397 | 1.673 | 0.474 | 1.462 | 0.505 |
| 5.0 | 114.084 | 41.708 | 121.432 | 34.227 | 99.506 | 45.956 | 99.849 | 37.376 | 114.865 | 35.676 | 133.026 | 34.741 |
| 6.1 | 12.634 | 7.188 | 13.521 | 8.662 | 14.918 | 8.262 | 19.387 | 8.526 | 20.289 | 8.537 | 17.231 | 9.247 |
| 6.2 | 18.695 | 7.281 | 17.776 | 7.240 | 20.506 | 7.587 | 25.630 | 6.577 | 25.327 | 6.471 | 24.692 | 7.142 |
| 7.1 | 19.840 | 7.673 | 21.763 | 6.589 | 20.094 | 7.154 | 19.891 | 7.020 | 19.673 | 6.609 | 20.974 | 4.928 |
| 7.2 | 20.206 | 6.568 | 21.379 | 6.156 | 18.177 | 7.559 | 19.731 | 6.499 | 21.481 | 6.581 | 20.949 | 7.000 |
| 7.3 | 15.840 | 7.828 | 16.610 | 6.695 | 15.500 | 8.458 | 17.269 | 7.104 | 17.904 | 7.381 | 16.410 | 7.007 |

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